Forage cactus in different cropping systems in the semi-arid region of Brazil*

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Abstract. Forage cactus is a Cactaceae grown in the Semiarid region of Brazil and other regions of the world, representing vital forage support. Using legumes in consortium with forage cactus can be an alternative in the region to increase the supply of nitrogen (N) in the soil and improve the quality of the animal diet. Thus, this study aimed to evaluate the yield of the different production systems with 'Míuda' Cactus (*Nopalea cochenillifera* Salm Dyck) and Mexican Elephant Ear [*Opuntia Sricta* (Haw.) Haw] in consortium with the 'Cunhã' legumes [*Clitoria ternatea* (L.)] and 'Jureminha' [*Demanthus pernambucanus* (L.) Thellung]. The experiment was carried out at the experimental farm of the Federal Rural University of Pernambuco (UFRPE), located in the municipality of Garanhuns-PE. A randomized block design with four replications was used. The experimental treatments were: T1 - Forage Cactus – Miúda + *D. pernambucanus*; T2 - Forage Cactus Miúda + *C. ternatea*; T3 - Forage cactus – Mexican Elephant Ear + *D. pernambucanus*; T4 - Forage cactus – Mexican Elephant Ear + *C. ternatea*; T5 - Forage Cactus – Miúda; T6 - Forage cactus – Mexican Elephant Ear; T7 - *C. ternatea;* and T8 - *D. pernambucanus*. The forage cactus was harvested after one year of cultivation, keeping the mother cladode, while the legumes were harvested every three months with a cutting height of 20 cm. Means were compared by Tukey's test at the 5% probability level. The width of the forage cactus showed different behavior in the arrangements, with the smallest width in the monoculture of forage cactus – Mexican Elephant Ear, which differed from the intercropping with *D. pernambucanus*. However, there were no differences in the monoculture and intercropping systems of Forage Cactus – Miúda. The Forage Cactus – Miúda showed the highest number of cladodes in all orders and greater thickness of the mother cladode in monoculture and in the intercropping with *D. pernambucanus*. Furthermore, the adoption of the system intercropped with legumes significantly affected the dry matter production of Forage Cactus and legume ($P<0.05$), with lower yields for the Forage Cactus – Miúda system in intercropping with *C.ternatea*. Altogether, it is concluded that the adoption of the intercropped system of cactus and legumes decreased the width of the *Opuntia stricta* when in consortium with *D. pernambucanus*. Likewise, it reduced the production of cactus and legume dry matter in the Forage Cactus – Miúda system, in consortium with *C. ternatea*.

Introduction

Forage production in the semi-arid region of Brazil is markedly influenced by the irregularity of rainfall. Due to that, the use of forage cactus is an important strategy for animal feeding. However, this cactus has limited levels of protein (Santos et al., 2022). To overcome this limitation, legumes have been used in consortium to increase the protein levels in the forage cactus and the supply of nitrogen (N) in the soil.

Thus, the objective of this study was to evaluate the yield of different production systems with Forage Cactus 'Míuda' (*Nopalea cochenillifera* Salm Dyck) and Mexican Elephant Ear [*Opuntia Stricta* (Haw.) Haw] in consortium with 'Cunhã' legumes [*Clitoria Ternatea* (L.)] and 'Jureminha' [*Demanthus pernambucanus* (L.) Thellung].

Methods and Experimental Site

The experiment was carried out at the Experimental Farm of the Federal Rural University of Pernambuco (UFRPE), located in the municipality of Garanhuns. The municipality is 896 meters above sea level, 1,030 meters from the highest point of the municipality, and is located in the mesoregion of the Agreste Meridional de Pernambuco, at 80 53' 2" South latitude and 360 29' 34" of west longitude.

A randomized block design with four replications was used. The experimental treatments were the different Forage Cactus and legume cropping systems in the following arrangements: T1 - Forage Cactus – Miúda + *D. pernmbucanus*; T2 - Forage Cactus – Miúda + *C. ternatea*; T3 - Forage Cactus – Mexican Elephant Ear + *D. pernmbucanus*; T4 - Forage Cactus – Mexican Elephant Ear + *C. ternatea*; T5 - Forage Cactus – Miúda; T6 - Forage Cactus – Mexican Elephant Ear; T7 - *C. ternatea;* and T8 - *D. pernambucanus*.

Soil preparation was carried out by plowing and harrowing, followed by correction and fertilization, based on the results of soil analysis. The experimental plot consisted of an area of 54 m^2 (6 m x 9 m). The forage cactus varieties in the intercropped treatments were planted in double rows with a spacing of 3.0 m x 1.0 m x 0.5 m and a planting density of 15,545 plants ha^{-1}. In the intercropped treatments, the legumes were planted between the double rows of the cactus in three single rows, with a spacing of 0.5 m between them and a density of 11,818 plants ha^{-1}. The single crops of palm and legumes followed the same spacing adopted in the intercropped plots with a spacing of 1.0 m x 0.5 m and a planting density of 20,000 plants ha^{-1}.

The management practices were carried out for each treatment with organic fertilization of foundation with 20 Mg ha^{-1} of bovine manure and periodic manual weeding. One year after planting, the following morphological characteristics were measured in forage cactus: plant height (PH), plant width (PW), number of total cladodes (NTC), number of primary cladodes (NPC), number of secondary cladodes (NSC), length (LC), width (WC), perimeter (PC) and thickness (TC) of cladodes of all the orders, which were obtained using a tape measure, except for the thickness, which was measured using a caliper, according to the methodology proposed by Donato et al. (2014).

For the cactus forage production data, ten rows with ten plants in the monoculture and four rows in the consortium of each plot were sampled and weighed on a scale to obtain the fresh weight. For the legumes, fresh weight production (PFW, kg $plant^{-1}$) was measured based on four plants evaluated in each plot every three months with a cutting height of 20 cm. After obtaining the PFW, the production of green matter (PGM, in Mg ha^{-1}) was calculated by the product between the PFW and the equivalent density of plants per hectare (DPH). According to the equation (PGM x (%DM), the production of dry matter (PDM, Mg ha^{-1}) was obtained.

The data were subjected to a residual normality test and analyzed using the PROC MIXED in SAS® OnDemand for Academics. The means were compared using Tukey's test, and the significance level adopted was 5%.

Results and Discussion

Higher plant height was observed for the *O. stricta cultivar*, regardless of the cultivation method. For the same species of forage cactus, there was no difference between the monoculture system and the intercropping. On the other hand, the plant width showed different behavior in the arrangements, with the monoculture of *O. stricta* differing from the intercropping with *D. pernambucanus*. However, in the monoculture and intercropping systems of *N. cochenellifera*, there was no difference.

The total number of cladodes and the number of primary and secondary cladodes did not differ between cultivars regardless of the cultivation system (Table 1). However, *N. cochenellifera* presented the highest number in all orders. It was also observed that the cactus *Opuntia stricta* did not present secondary cladodes, while *N. cochenellifera* presented a higher number of secondary than primary cladodes.

Table 1. Effect of cactus-legume intercropping on the morphological characteristics of Forage Cactus

Systems	PH (cm)	PW	NTC	NPC	NSC	PMV ($Kg.ha^{-1}$)
'Miuda'	33,50c	43,75b	9,75a	4,69a	7,06a	15122,5
'Miuda'+'Cunhã'	35,06bc	48,62ab	12,81a	5,12a	6,37a	13551,36
'Miuda'+'Jureminha'	36,75bc	52,56ab	12,19a	4,37a	5,06a	15468,25
O. stricta	40,87ab	57,12a	2,5b	2,5b	0b	23081.78
O. stricta +'Cunhã'	39,59ab	54,09ab	2,19b	2,19b	0b	17141,28
O. stricta +'Jureminha'	42,97a	46,19b	2,56b	2,56b	0b	17443,92
P-value	0,0001	0,0107	0,0001	0,0001	0,0001	0,9632

PH = plant height; PW = plant width; NTC = number of total cladodes; NC1 = number of 1st order cladodes; NC2 = number of 2nd order cladodes; PGM = production of green matter. Means followed by the same letter in the column showed no significant difference between them by Tukey's test at 5%.

The number of secondary cladodes can be associated with the cultivar. Cactus varieties that have a greater number of cladodes are potential alternatives for animal feed, as well as having more material for planting.

For the length of the primary and secondary cladodes, the width of the mother, primary cladodes and secondary cladodes, perimeter of the mother, primary, and secondary cladodes, there were no differences between the cultivars in the intercropping monoculture (Table 2). The thickness of the mother cladode differed for *Nopaela*, with greater thickness in monoculture and in the intercropping with *Desmanthus*.

The adoption of the intercropped system with legumes significantly affected the production of dry matter of cactus ($P<0.05$). A lower yield for cactus *N. cochenellifera* was observed when intercropped with *C.ternatea* (Table 3). Furthermore, this consortium reduced the dry matter production of the legume, which did not differ from the consortium of *N. cochenellifera* with *D.pernambucanus*. On the other hand, for *D. pernambucanus*, there was no difference in the production of the monoculture when compared to the intercropping system. It is worth mentioning that *D. pernambucanus* showed a higher yield regardless of the cultivation system (Table 4).

Conclusions

The adoption of the cactus and legumes intercropped system decreased the width of *Opuntia stricta* cactus in consortium with *D. pernambucanus* and decreased cactus and legumes dry matter production in the *N. cochenellifera* system in consortium with *C. ternatea*.

Desmathus pernambucanus showed a higher yield than *Clitoria ternatea*, regardless of the cropping system.

References

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Table 2. Effect of cactus-legume intercropping on cactus morphological characteristics

	'Miuda'	'Miuda' + 'Cunhã'	'Miuda'+ 'Jureminha'	*O. stricta*	*O. stricta* + 'Cunhã'	*O. stricta* +'Jureminha'	P-value
				length of cladodes (cm)			
CCM	15,06d	17,37cd	19,75c	28,75a	24,87b	27,12ab	0,0001
CC1	17,45b	18,81b	19,58b	26,32a	28,05a	27,81a	0,0001
CC2	12,05a	12,33a	12,71a	0b	0b	0b	0,0001
				Width of cladodes (cm)			
LCM	11,37b	11,44b	15,09b	30,5a	32,65a	29,68a	0,0001
LC1	8,66b	8,84b	9,22b	23,29a	23,77a	23,36a	0,0001
LC2	5,64a	6,37a	6,82a	0b	0b	0b	0,0001
				Thickness of cladodes (cm)			
ECM	2,57b	3,03a	2,99ab	1,82c	1,72c	1,77c	0,0001
EC1	2,39	1,65	1,99	1,31	1,36	1,21	0,1058
EC2	0,68a	0,85a	1,00a	0b	0b	0b	0,0001
				Perimeter of cladodes (cm)			
PCM	33,44c	36,94c	44,87b	69,06a	63,81a	67,37a	0,0001
PC1	39,46b	41,66b	45,96b	73,07a	76,09a	74,90a	0,0001
PC2	26,46a	29,18a	29,84a	0b	0b	0b	0,0001

LMC = length of mother cladodes, L1OC = length of 1st order cladodes, L2OC = length of 2nd order cladodes, WMC = width of mother cladodes, W1OC = width of 1st order cladodes, W2OC = width of 2nd order cladodes, TMC = thickness of mother cladodes, T1OC = thickness of 1st order cladodes, T2OC = thickness of 2nd order cladodes, PMC = perimeter of mother cladodes, P1OC = perimeter of 1st order cladodes, P2OC = perimeter of 2nd order cladodes. Means followed by the same letter, in the column, showed no significant difference between them by the Tukey's test at 5%.

Table 3. Effect of cactus-legume intercropping on cactus dry matter production.

Systems	PGM (kg.ha^{-1})	P-value
'Miuda'	1518,70ab	0,0410
'Miuda'+'Cunhã'	1378,61b	
'Miuda'+'Jureminha'	1486,08ab	
O. stricta	3226,92a	
O. stricta +'Cunhã'	1766,67ab	
O. stricta +'Jureminha'	2092,31ab	

PGM = production of green matter. Significant P-value based on the Tukey's test at 5%.

Table 4. Effect of cactus-legume intercropping on legume dry matter production.

Systems	DMP (kg.ha^{-1})	P-value
'Cunhã'	989,89a	0,0380
'Miuda'+'Cunhã'	494,04b	
O. stricta +'Cunhã'	558,98b	
'Jureminha'	1039,89a	
'Jureminha'+'Miuda'	1372,86a	
O. stricta +'Jureminha'	1164,54a	

DMP =Dry matter production. Significant P-value based on the Tukey's test at 5%.